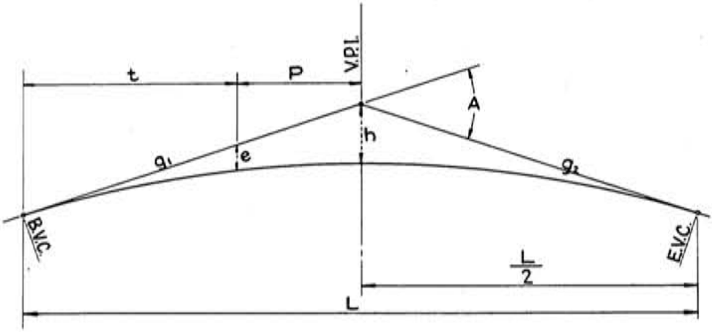
VERTICAL CURVE EQUATIONS STANDARDS



LEGEND	EQUATIONS
g_1 & g_2 = Intersecting gradients in %	
A = Algebraic difference in gradients	$A = (\pm g_2) - (\pm g_1)$
L = Length of vertical curve in stations	
B.V.C. = Beginning of Vertical Curve	$h = \frac{AL}{8}$
E.V.C. = End of Vertical Curve	
V.P.I. = Vertical Point of Intersection	
t = Horizontal distance to any point on the curve from B.V.C. or E.V.C. in stations	$e = \frac{4ht^2}{L^2}$
P = Horizontal distance to any point on the curve from the V.P.I. in stations	
h = Vertical distance from point of intersection to the curve V.P.I. in feet	
e = Vertical distance at any point on the curve to the tangent grade in feet	$e = Kt^2$
K = A constant for any particular curve = $\frac{A}{2L}$	$e = \frac{At^2}{2L}$
L_1 = Length of a vertical curve which will pass through a given point	$= \frac{2(AP + 2e + 2\sqrt{APe + e^2})}{A}$

VERTICAL CURVE EQUATIONS

SLIDE-RULE METHOD

1. Place algebraic difference in gradient (a) on the B scale opposite 2 times the length of the vertical curve (2L) on the A scale.
2. Set the hairline of the indicator over 1/2L on the D scale. 1/2L squared will then be under the hairline on the A scale and H will appear on the B scale.
3. Without moving the slide, move the indicator to any distance t on the D scale and the correction will appear on the B scale under the hairline.

ALTERNATE SLIDE RULE METHOD

Compute the value for "h" and place on the A or square scale of the slide rule. Opposite this value on the A scale set ½ of the value for "L" on the C scale. Any value for "e" can be obtained by sliding the indicator hairline to the desired distance from the beginning of curve BVC or End of curve EVC on the C scale and reading the correction to 3 significant digits on the A scale.

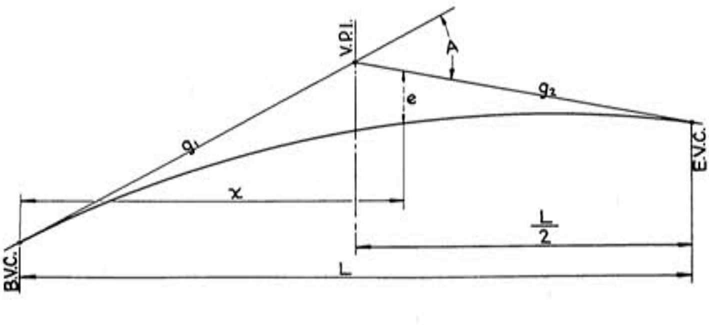
Percent of Grade at any distance from B.V.C.

$$\% \text{ Grade} = g_1 - \frac{At}{L}$$

Distance from B.V.C. to a 0.0% Grade Point.

$$t = \frac{(g_1)L}{A}$$

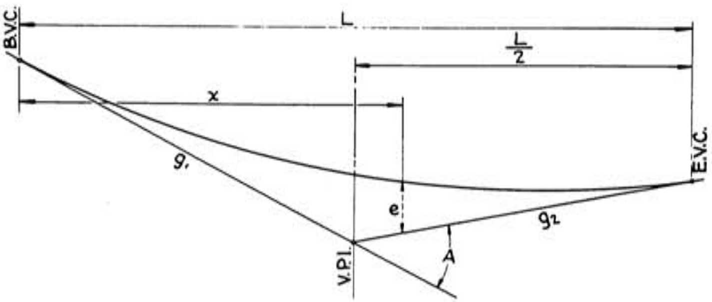
HIGH POINT OF A SUMMIT CURVE OR LOW POINT OF A SAG CURVE



VERTICAL CURVE EQUATIONS

HIGH POINT OF A SUMMIT CURVE OR LOW POINT OF A SAG CURVE (Cont.)

LEGEND	EQUATIONS
g_1 = Approach gradient in % A = Algebraic difference in gradients L = Length of vertical curve stations B.V.C. = Beginning of Vertical Curve V.P.I. = Vertical Point of Intersection E.V.C. = End of Vertical Curve X = Distance from the B.V.C. to the low or high point in stations.	$X = g_1 \left\{ \dfrac{L}{A} \right\}$



EXAMPLE FOR A SAG CURVE

Given:

$g_1 = -3.00\%$, $g_2 = +2.00\%$, $L = 4.00$, $A = 5.00$

Required:

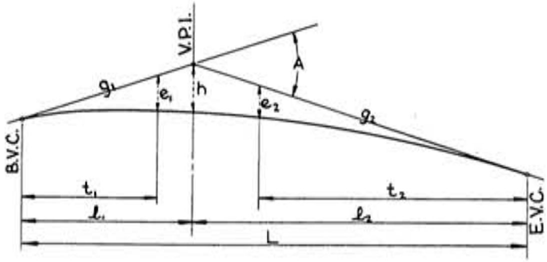
X and e

Solution:

$$X = 3.0 \left\{ \frac{4.0}{5} \right\} = 2.4 \text{ stations}$$

VERTICAL CURVE EQUATIONS

NONSYMMETRICAL CURVES



LEGEND	EQUATIONS
g_1 & g_2 = Intersecting gradients in %	
A = Algebraic difference in gradients	
l_1 = Length of ½ of first vertical curve in stations	$h = \dfrac{l_1 \quad l_2}{2\,(l_1 + l_2)} A$
l_2 = Length of ½ of second vertical curve in stations	
L = Length of vertical curve in stations $= l_1 + l_2$	
B.V.C. = Beginning of Vertical Curve	
V.P.I. = Vertical Point of Intersection	$e_1 = h \left\{ \dfrac{t_1}{l_1} \right\}^2$
E.V.C. = End of Vertical Curve	
t_1 = Horizontal distance to any point on the curve from B.V.C. to V.P.I. in stations	$e_2 = h \left\{ \dfrac{t_2}{l_2} \right\}^2$
t_2 = Horizontal distance to any point on the curve from E.V.C. to V.P.I. in stations	
e_1 = Vertical distance at any point on the curve from B.V.C. to V.P.I. in feet	
e_2 = Vertical distance at any point on the curve from E.V.C. to V.P.I. in feet	
h = Vertical distance from point of intersection to the curve (V.P.I.) in feet	

NONSYMMETRICAL CURVES (Cont.)

EXAMPLE

Given:
$g_1 = +\ 3.00\%$, $g_2 = -\ 2.00\%$, $l_1 = 1.50$, $l_2 = 2.50$, $t_1 = 0.50$, $t_2 = 1.00$

Required:
h, e_1, e_2

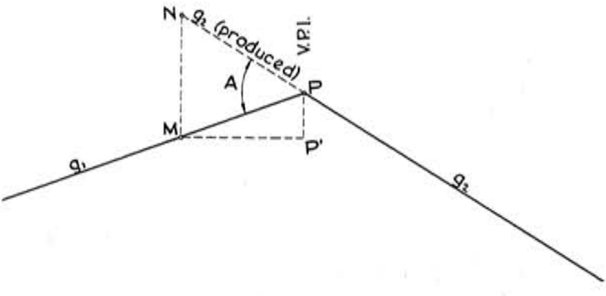
Solution:

$$h = \frac{1.50(2.50)}{2(1.50+2.50)} \left\{ (+3.00) - (-2.00) \right\} = \frac{3.75}{2(4.00)} (+5.00) = 2.34 \text{ ft.}$$

$$e_1 = 2.34 \left\{ \frac{0.50}{1.50} \right\}^2 = 2.34\ (.3333)^2 = 2.34\ (.1111) = 0.26 \text{ ft.}$$

$$e_2 = 2.34 \left\{ \frac{1.00}{2.50} \right\}^2 = 2.34\ (.40)^2 = 2.34\ (.16) = 0.37 \text{ ft.}$$

DETERMINING INTERSECTION OF GRADES



$$\text{Equation: } MP' = \frac{100 \times MN}{A}$$

Legend: A = Algebraic difference in gradients = $(\pm g_1) - (\pm g_2)$

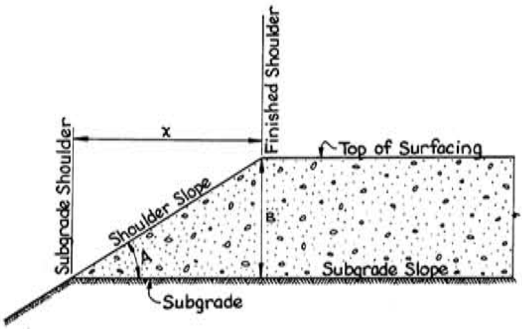
M = Known station

MN = Difference in elevation in feet between elevation of M on true gradient and on opposite gradient produced

MP' = Horizontal distance in feet from M to point of intersection of gradients

V.P.I. = Vertical point of intersection

DETERMINATION OF DISTANCE FROM FINISHED SHOULDER TO SUBGRADE SHOULDER AND SLOPE EQUIVALENTS



$$\text{Equation: } X = \frac{100B}{A}$$

A = Algebraic difference in percent between shoulder slope and subgrade slope

B = Depth of surfacing at finished shoulder

X = Distance from finished shoulder to subgrade shoulder

SHOULDER SLOPE	EQUIVALENT RATE OF GRADE	EQUIVALENT VERTICAL ANGLE
1.5 :1	66.67%	33° 41.4′
1.75:1	57.14%	29° 44.7′
2 :1	50.00%	26° 33.9′
2.5 :1	40.00%	21° 48.1′
3 :1	33.33%	18° 26.1′
4 :1	25.00%	14° 02.2′
5 :1	20.00%	11° 18.6′
6 :1	16.67%	9° 27.7′
8 :1	12.50%	7° 07.5′
10 :1	10.00%	5° 42.6′

SUBGRADE SLOPE	EQUIVALENT RATE OF GRADE	EQUIVALENT VERTICAL ANGLE
.02′ /1	2.00%	1° 08.7′
.025′/1	2.50%	1° 25.9′
.03′ /1	3.00%	1° 43.1′
.035′/1	3.50%	2° 00.3′
.04′ /1	4.00%	2° 17.4′
.05′ /1	5.00%	2° 51.7′

PILE DRIVING FORMULAS

For Gravity Hammers $$P = \frac{2WH}{S+1.0}$$

For Single Acting Steam or Air Hammer $$P = \frac{2WH}{S+0.1}$$

For Double Acting Steam or Air Hammer $$P = \frac{2H\,(W+A_p)}{S+0.1}$$

WHERE P = Safe Bearing Power in pounds.

W = **Weight of striking part of hammer in pounds. (For drop hammers this weight should not be less than 3,000 lbs. for piling less than 50 feet in length, nor less than 4,000 lbs. for piling longer than 50 feet in length.)**

H = Drop of hammer or stroke of ram, in feet. (For wooden piling this max. height shall be 10 feet.)

A = Area of Piston in Square Inches.

p = Steam pressure in pounds per square inch at the hammer.

S = The average penetration in inches per blow for the last 5 – 10 blows for gravity hammers or the last 10 – 20 blows for steam or air hammers.

The above formulas are applicable only when:

(a) The hammer has a free fall.

(b) The head of the pile is free from broomed or crushed wood fiber.

(c) The penetration is at a reasonably quick and uniform rate.

(d) There is no sensible bounce after the blow. Twice the height of the bounce shall be deducted from "H" to determine its true value in the formula.